NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

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MEETING ANNOUNCEMENT

DATE: Wednesday, April 24, 2024

LOCATION: Orinda Masonic Hall

TIME: Social time: 6:30 to 7:15 pm; Program: 7:15 to 8:30 pm

SPEAKER: ***Nicholas Swanson-Hysell, UC, Berkeley***

TOPIC: ***"Chronostratigraphy of Miocene strata in the Berkeley Hills and the arrival of the San Andreas transform boundary"***

Abstract:

In this talk, I will present recent results from undergraduate honors theses projects in the Earth and Planetary Science Department at UC Berkeley that bring new constraints to the Miocene geological evolution of the portion of the California Coast Ranges in our backyard. New chronostratigraphic constraints from the Berkeley Hills assemblage that builds upon work in the Mount Diablo GSA volume were recently published by our group as Gerasimov et al. 2024 (https://doi.org/10.1130/GES02650.1). A sandstone from the Claremont formation produced a detrital zircon chemical abrasion–isotope dilution–thermal ionization mass spectrometry (CA-ID-TIMS) maximum depositional age of 13.298 ± 0.046 Ma, indicating younger Claremont deposition than previously interpreted. A trachydacite tuff clast within the uppermost Orinda Formation yielded a CA- ID- TIMS U-Pb zircon date of 10.094 ± 0.018 Ma, and a dacitic tuff within the Moraga Formation produced a CA-ID-TIMS U-Pb zircon date of 9.974 ± 0.014 Ma. These results indicate rapid progression from subsidence in which deep- water siliceous sediments of the Claremont formation were deposited to uplift that was followed by subsidence during deposition of terrestrial sediments of the Orinda Formation and subsequent eruption of the Moraga Formation volcanics. We associate the Orinda tuff clast and Moraga volcanics with slab-gap volcanism that followed the passage of the Mendocino triple junction. Given the necessary time lag between triple junction passage and the removal of the slab that led to this volcanism, subsidence associated with ca. 13 Ma Claremont sedimentation and subsequent Orinda to Moraga deposition can be attributed to basin formation along the newly arrived transform boundary. In addition to these data, I will present new results from the Northbrae rhyolite of Berkeley and the Burdell Mountain volcanics of the North Bay. This work confirms the Neogene slab-gap volcanic interpretation for the Northbrae and strengthens the Northbrae-Burdell correlations through new petrography, trace element geochemistry, and geochronology. A fascinating aspect of this correlation is that it indicates that ~20% of the offset of the East Bay Fault system occurred to the west of the modern-day Hayward Fault.

NCGS 2023 – 2024 Calendar

May 29, 2024 Social 6:00 – 6:45 pm; Dinner 6:45 – 8:00 pm; Presentation 8:00 – 9:00 pm

(Dinner meeting)

Libby Ives, Jet Propulsion Laboratory (NASA/Caltech)

Sedimentary geology of the Jezero crater western fan as seen by NASA's Mars Perseverance rover

June 26, 2024 7:15 pm (6:30 social time)

Don Medwedeff, Consultant

Structure, Timing, and Western Extent of the Stockton Arch: Constraints on Neogene strike slip fault offset in the Diablo Range

Next Month's Dinner Meeting

Please use the following link on RegFox to reserve your space at the dinner meeting in May:

https://ncgs.regfox.com/ncgs-dinner-meeting-may-2024

The speaker and topic are listed in the foregoing box. Come and enjoy social time, a barbeque dinner, and an excellent talk with your NCGS friends – courtesy of the Back Forty!

New Youtube Channel:

By vote of the Board in May 2023, we returned to in-person meetings only, as of the September 2023 meeting. We will still record the meetings to Zoom for archiving on our new YouTube channel, @NCGS1000 (which you can access now by typing in the entire name @NCGS1000 into the search bar for Google or YouTube). This is where recently recorded talks can be accessed a few days after each meeting, or past talks recorded since September 2022 can be reviewed at any time. Only talks for which authors have given permission for this archiving will be accessible.

Invitation For New Officer Appointment

Due to the recent resignation of our Secretary, Steve Self, for personal reasons, we are looking to appoint a new secretary to fill the rest of Steve's elected term (through August 31, 2024) and potentially to stand for re-election next June. Please contact President Jim O'Brient or Past President Noelle Schoellkopf if you are interested or have a candidate to suggest. The duties are few, but vitally important to the society:

(1) The **Recording Secretary** shall attend and take notes at all Executive Committee board meetings (typically three times per year) and shall notify the members of proposed amendments to the Constitution and Bylaws.

(2) When any other membership-wide communication is required, assist other officers in sending out email and occasional postal communications. Note: Since NCGS has moved to a new web-based system for emails, sign-ups, and payments (RegFox), this will chiefly be a consulting role to help others such as the President, Newsletter Editor, Treasurer, Membership Chair, Program Chair, or Field Trip Chair, all of whom will be trained on sending out such messages directly.

(3) Maintain Google drive folders and access for our archive of past information.

(4) Maintain hard cc files (as backup) only for critical Society records.

(5) Serve as alternate check signer when neither Treasurer nor President is available.

Raymond Sullivan

October 27, 1934 – January 13, 2024

NCGS stalwart Raymond Sullivan passed away on January 13, 2024, at the age of 89. Ray, as he was known by friends, family, and students alike, is survived by his loving wife Barbara of 61 years and his sons Morgan and Gareth. He was also the proud grandfather of Conor, Caitlin & Liam.

Ray was born in Ebbw Vale, a steel and coal town hidden away in the mountains of South Wales. He was one of nine children and worked hard to overcome the challenges he and his family faced. In his youth, Ray and his older brother, Herbert, roamed the surrounding hills and moorlands and became fascinated with the landscape around them. Ray's idea of studying geology came from a newspaper article on the subject and at the time he had no idea that one day three generations of Sullivans would end up studying geology. He received a B.Sc. in Geology from Sheffield University and a Ph.D. from the University of Glasgow in Scotland.

After university, Ray emigrated to Canada and spent his early years with Shell and met Barbara Brown on a sleigh ride in Edmonton, Alberta during the winter of 1961. They married the following year before setting off to California for Ray's new position at San Francisco State University. The happy couple were later blessed to welcome two sons, Morgan and Gareth, both of whom followed in their father's footsteps by majoring in geology. Barbara continued to work in the travel industry while embracing university faculty associates and supporting Ray in his

professional career, serving as field assistant, secretary, manuscript editor, adviser, and confidant.

Ray spent 40 years teaching geology and earth science at San Francisco State. During this time, he helped co-found the Department of Geology, was Associate Dean of Science, a Fellow of the California Academy of Sciences, and was awarded the university's highest "Inspiring Teacher" award at least five times. He was an inspiration to his students and the public for well over 50 years. In the words of one of his students, "he achieved this by making geology come alive in lectures and relating the rocks to our very existence."

Ray retired from the Department of Geosciences at San Francisco State University in 1997 but continued to teach part-time until 2002 to complete his 40 years. For the past 20 years, Ray and Barbara traveled widely and visited many interesting places including Easter Island, Fanning Island, Iceland, American Samoa, Midway Island, Devils Island, Beagle Channel, Patagonia, Amazon River, Russia, Ukraine, Oman, Egypt, Zimbabwe, South Africa and the country of his birth, Wales.

Not one to rest on his laurels during retirement, Ray continued to lead field trips for the Northern California Geological Society and other groups, publish papers, and conduct mapping and research in Contra Costa County. He was president of, and remained active in, NCGS, with the culmination of his efforts being the conception, recruiting of authors, editing and being the sine qua non of the recently published GSA Memoir 217, Regional Geology of Mount Diablo, California: Its Tectonic Evolution on the North America Plate Boundary.

Ray led field trips for the public in downtown San Francisco a number of times. For many years he led trips for teachers during Earth Science Week to the Black Diamond historical coal mining area and also in downtown San Francisco. He served on a multitude of professional society and consortium committees, chairing some, and led field trips to Black Diamond mines for petroleum company geologists. He served a term as delegate to the American Association of Petroleum Geologists House of Delegates and received AAPG's Lifetime Achievement and Exemplary Service awards as recognition of his outstanding contributions and support of higher education and educating the public.

Ray will be remembered as someone who gave 100%. To Barbara, he gave his heart. To his sons, he gave advice and guidance. To his grandchildren, he gave stories and dreams to be fulfilled. To his friends, he gave friendship that knew no limits. He will be greatly missed.

Website News

From Andrew Alden, NCGS Website Manager/Social Media

Earlier this month, I finally found time to write up a report on our memorable field trip to the Sutter Buttes. You'll find the link in the table of past field trips, in 2007. This is part of my personal effort to fill out NCGS's long and admirable record of excursions. Speaking of which, I made a thorough search of my files and located hard copies of three previously missing field-trip guides that I will have rendered into PDFs for posting on the website. I urge other NCGS members to do the same! One of them was for our Napa Valley field trip in the early spring of 2016. Another will be of interest to this month's speaker: Lin Murphy's field trip to the Northbrae Rhyolite in 2003.

Aside from the NCGS Newsletter and word-of-mouth, our only ways of reaching more people are through our website and social media. You can help NCGS grow and thrive by sharing NCGS news in your social-media circles. A simple first step is to add the Society to your profiles wherever they are, preferably with a link to https://ncgeolsoc.org. You can also send me interesting news items for posting from our Xitter account or Facebook page.

The Northern California Geological Society's

RICHARD CHAMBERS MEMORIAL SCHOLARSHIPS

2023-2024 AWARDS

The NCGS is pleased to announce that it is awarding $2,000 scholarships to two graduate students pursuing research in northern California. The availability of the Richard Chambers Memorial Scholarship is announced to all Colleges and Universities having graduate programs in northern California. These scholarships are funded from the Richard Chambers Memorial Scholarship fund and donations made by NCGS members and others for scholarships. These two students were chosen from a collection of well-prepared applications made to the NCGS during the fall of 2023. Serving on the NCGS Scholarship Committee were Phillip Garbutt (chair), Andrew Alden, Don Medwedeff, Noelle Schoellkopf and Will Schweller.

The recipients are:

Eden Pikowski, CSU Chico, for a master's research proposal titled ***"Paleoecology of the hydrocarbon seeps***

of Blue Ridge, Colusa, County, CA". Project advisor is Dr. Robert Shapiro.

Evelyn H. Usher, for a master's degree research proposal titled: ***"Transition from Walker Lane deformation to Cascade Range faulting and volcanism within Lassen National Park".*** Project advisor is Dr. Michael Oskin.

UC Berkeley Earth & Planetary Science Weekly Seminar Series

In-person EPS Seminar talks have resumed for the semester and are scheduled through the academic year. On Thursday, April 25, 2024 at 3:45 pm, Yiming Zhang, UCSB will speak on ***Reconstructing late Proterozoic magmatism, geomagnetic field behavior, and paleogeography using tiny magnets in rocks*** at 141 McCone Hall. To join the department's email list, send an email to eps_frontoffice@berkeley.edu. For updated listings of upcoming seminars, go to https://eps.berkeley.edu/seminars-courses/eps-seminars.

For the Rockhounds

For links to upcoming rock and mineral shows, go to www.cfmsinc.org/shows.

USGS Evening Public Lecture Series

The USGS evening public lecture series events are free and are intended for a general public audience that may not be familiar with the science being discussed. Pre-Covid, talks were held at USGS; the talks are now online. **Talks had been scheduled through June, but USGS is currently taking a pause on their Virtual Public Lecture Series. In the meantime, take a look at their archive for their past lectures!** To be added to the email notification list for future USGS Public Lecture Series events, email: wmcesic@usgs.gov.

2023-2024 NCGS Registration and Dues

A 21st Century Innovation Takes Hold

Following a successful pilot for August's field trip, NCGS is converting from last century's check-based system for membership renewal, field trip registration, and dinner meeting registration, to an electronic system. The system is hosted by RegFox, which is a fee-per-use system, with no software or internet costs to the NCGS. The fees per registration, which are 2.99% + $0.99 per registration (or $1.71, $2.49, or $3.24 for 1, 2, and 3-year registrations, respectively), will be covered by the NCGS.

To cover these new fees and increased costs for hall-rental, mailings, web-hosting, and insurance, the board approved an increase in dues beginning September 1st to $25 annually for membership and $25/annually for surcharge for paper mailing.

All registrations will be accessed via this link: https://NCGS.regfox.com/ncgs-landing. This brings up an electronic version of the legacy NCGS Membership page (see attached figure). This page will always be active and a link to it will be included in the Newsletter and sent annually to members whose renewal date has arrived. Funds received are directly deposited in the NCGS account and membership details are immediately available to the Membership Secretary for recording.

Registration for Field Trips or the Annual Dinner Meeting will be accessed from the tabs above the Membership Renewal form. These tabs will be grayed out when inactive and highlighted when active. The electronic system is particularly effective for these time-sensitive reservations, as trip availability and dinner commitments are instantaneously updated for both organizers and attendees.

Final Note: If you are among those unable to use the electronic registration, you can contact me (Don M.) via mail at 146 Roan Drive, Danville, CA 94526.

Regards,
Don Medwedeff
NCGS Treasurer

WE'RE ON FACEBOOK!
CHECK OUT THE MOST RECENT POST: @NCGEOLSOC
ALSO, VISIT TWITTER @NORCALGEOSOC

NCGS Board Meetings

Board meetings (online for now) are open to all NCGS members. If you'd like to attend, please contact Jim O'Brient at j.obrient @ comcast.net. Board meetings generally are on Saturday mornings in Jan., Apr./May, and Aug./Sep. Upcoming meeting: **Saturday, May 18, 2024 at 9 a.m., by Zoom**.

A Great Website to Visit

Last year Dr. Ray Sullivan completed an excellent website – see http://raysullivangeologist.com/. As many of you know, Ray was a longtime professor of geology at San Francisco State University as well as serving in multiple positions with other societies and organizations, and with NCGS as president, program chair, field trip leader and

counselor, and co-editor of the Mount Diablo volume recently published with the Geological Society of America. The website has a biography, list of journal and book publications, and a list of projects on which he worked, with some great photos and stories.

-- Book Review --

How the discovery of dinosaur fossils caused a revolution

"Impossible Monsters" looks at 70 years that changed human thought

The Economist, Mar 20th 2024

Impossible Monsters. By Michael Taylor. Bodley Head; 496 pages; £25. To be published in America by Liveright in July; $32.99

An intellectual revolution began in 1811 when Mary Anning, a 12-year-old living in Lyme Regis, a harbour town in south-west England, excavated the first fossil of a marine reptile, the Ichthyosaurus. It culminated in 1881 with the opening of the Natural History Museum in London, imperial capital of the world, by Richard Owen. Those seven decades spanned a change in thinking as profound as that triggered by the astronomers of the late Renaissance—and as disturbing to the established church. (In this case, the threatened church was that of England, not Rome.) Fossils sparked a revelation of biblical proportions: God had not created the world in six days a few thousand years before, as so many believed.

"Impossible Monsters" is a story about time—or, rather, two parallel stories. In one, time moves forward, as the players take turns making remarkable discoveries that help advance science and humans' understanding of their place in the world. In the second, it moves backwards, as the years needed to accommodate the findings of geologists and naturalists expand from thousands, to hundreds of thousands, to millions, pushing the date of "Creation" further away.

In writing "Impossible Monsters", the task of Michael Taylor, a historian, was to tell a much-told tale better than it had been told before. He has succeeded splendidly. The cast is many and varied, including Anning, a lowly fossil-seller, who achieved international fame through her discoveries—*Ichthyosaurus* was but the first—yet was barred from joining the Royal Geological Society because of her sex. Many are memorably idiosyncratic, such as William Buckland, an eccentric Oxford don who once ate a mummified morsel of Louis XIV's heart. He is better remembered for identifying and naming *Megalosaurus*, the first of the group subsequently dubbed "dinosaurs".

Some of the characters are familiar, like Charles Darwin (no introduction needed, unless you live somewhere his theory is banned from textbooks). But many are less well known, such as Alfred Russel Wallace, a collector and seller of tropical specimens, who devised the idea of natural selection independently. Thomas Huxley, Darwin's self-appointed "bulldog", became chief mover and shaker for all things official and scientific in Victorian Britain. Owen, Huxley's enemy, held out against Darwin's ideas, yet forced through the construction of the museum many now regard as evolution's temple.

It is a grand pageant. But Mr. Taylor also conveys a sense of just how risky it was to believe in and promulgate the new ideas tied to the rocks and tropical forests where people hunted for specimens. Some clergymen, Buckland among them, performed intellectual contortions to reconcile the bones with the Bible. Even Darwin, wealthy and well-connected (and at one point himself destined for the church), at first lived in fear of the disgrace that might accrue if his ideas became public.

The intellectual climate changed, of course. However, lest readers congratulate themselves too readily on their enlightenment, it is salutary to consider, as the book's prologue does, the case of James Ussher, an Anglo-Irish archbishop who lived in the 17th century. Ussher devoted his life to calculating the exact date of God's creation of the world. Unlike some of his 19th-century ecclesiastical successors, he cannot be accused of ignoring or twisting the evidence. He spent decades and a fortune assembling dusty tomes that gave him what he thought were the data points he needed to anchor biblical passages in time, just as a modern geologist might use the radiometric evidence of volcanic-ash layers to date a series of strata.

Ussher's conclusion was that the world began on October 22nd 4004 BC. It is an idea that sounds almost as prehistoric as a fossil. But who knows what widely accepted notions of today will also go extinct? ■

This article appeared in the Culture section of the print edition of *The Economist* under the headline "Jurassic spark."

Surprising insights about debris flows on Mars

Research pushes the presence of water on Mars further into the past

EurekAlert!, March 14, 2024
Source: Utrecht University

The period that liquid water was present on the surface of Mars may have been shorter than previously thought. Channel landforms called gullies, previously thought to be formed exclusively by liquid water, can also be formed by the action of evaporating CO_2 ice. That is the conclusion of a new study by Lonneke Roelofs, a planetary researcher at Utrecht University. "This influences our ideas about

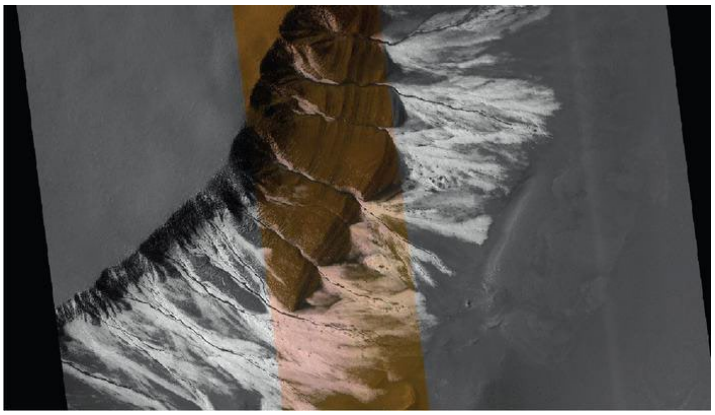


Image: Satellite image of gully landscapes on Mars, taken by HiRISE (High Resolution Imaging Experiment), a camera on board the Mars Reconnaissance Orbiter (photo no.: ESP_039114_1115). The white CO_2 ice is visible on the sides of the gullies.

Credit: HiRISE (High Resolution Imaging Experiment), a camera on board the Mars Reconnaissance Orbiter

water on Mars in general, and therefore our search for life on the planet." The results of the study are published this week in the journal Communications Earth and Environment.

"The Martian atmosphere is 95% CO_2", Lonneke Roelofs explains. "In winter, air temperatures drop below -120 degrees Celsius, which is cold enough for CO2 in the atmosphere to freeze." In the process of freezing, CO_2 gas can change directly to CO_2 ice, skipping the liquid phase. The process is similar to frost on Earth, where water vapour forms ice crystals and blankets the landscape in a white film. Warmer spring temperatures, combined with the thin Martian atmosphere, causes CO_2 ice to evaporate directly back to gas, again skipping the liquid phase. "We call that 'sublimation'. The process is extremely explosive due to Mars' low air pressure. The created gas pressure pushes sediment grains apart causing the material to flow, similar to debris flows in mountainous areas on Earth. These flows can reshape the Martian landscape – even in the absence of water."

"The results of my research suggest that the chance of life having existed on Mars is smaller than previously thought."

Scientists have long hypothesized that CO_2 ice could be a driving force behind these Martian landscape structures. "But those hypotheses were mainly based on models or satellite studies", Roelofs explains. "With our experiments in a so-called 'Mars chamber', we were able to simulate this process under Martian conditions. Using this specialized lab equipment we could directly study this process with our own eyes. We even observed that debris flows driven by CO_2 ice under Martian conditions flow just as efficiently as the debris flows driven by water on Earth."

Extraterrestrial life

"We know for sure that there was once water on the surface of Mars. This study does not prove the contrary", Roelofs says. "But the emergence of life likely needs a long period where liquid water was present. Previously, we thought that these landscape structures were formed by debris flows driven by water, because of their similarity to debris flow systems on Earth. My research now shows that, in addition to debris flows powered by water, the sublimation of frozen CO_2 can also serve as a driving force behind the formation of these Martian gully landscapes. That pushes the presence of water on Mars further into the past, making the chance of life on Mars smaller." And that makes us even more unique than we thought.

Why Mars?

But what makes someone interested in landscapes 330 million km away? "Mars is our closest neighbor. It's the only other rocky planet close to our solar system's 'green zone'. The zone is precisely far enough from the sun to allow for liquid water to exist, a prerequisite for life. So Mars is a place where we possibly can find answers to questions about how life developed, including potential extraterrestrial life", answers Roelofs. "Plus, studying the formation of landscape structures on other planets is a way for us to step outside our Earthly context. You ask different questions, which leads to new insights on processes here on Earth. For example, we can also observe the process of gas-driven debris flows in pyroclastic flows around volcanoes, here on Earth. So this research could contribute to a better understanding of terrestrial volcanic hazards."

Journal Reference: How, when, and where current mass flows in Martian gullies are driven by CO_2 sublimation, *Communications Earth & Environment.* DOI*:* 10.1038/s43247-024-01298-7. Publication Date: 13-Mar-2024.

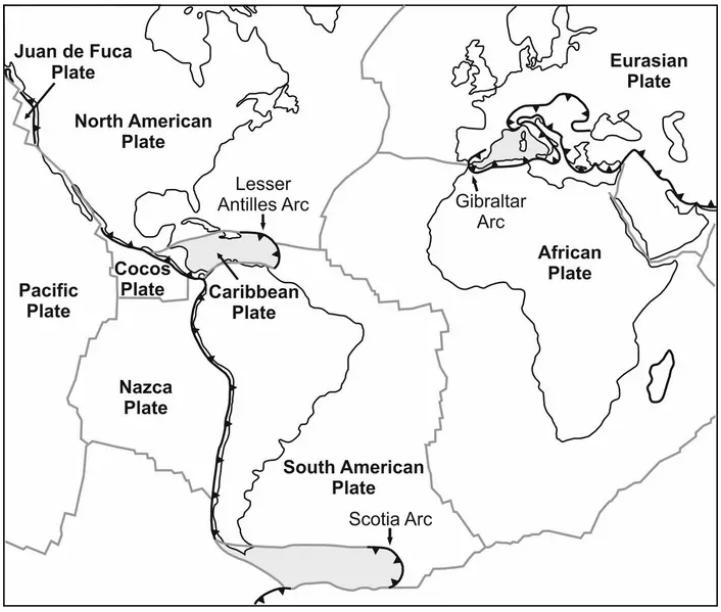
From the Mediterranean into the Atlantic: The Gibraltar arc is migrating to the west

After a period of quiescence, the subduction zone under the Strait of Gibraltar will continue to invade the Atlantic Ocean

EurekAlert! March 19, 2024
Source: Johannes Gutenberg Universitaet Mainz

Oceans are subject to continuous change, mostly over extremely vast periods of time running into millions of

years. Researchers from Universidade de Lisboa in Portugal and Johannes Gutenberg University Mainz (JGU) in Germany now used computer simulations to demonstrate that a subduction zone originating in the Western Mediterranean will propagate into the Atlantic under the Strait of Gibraltar. According to their model, this will create a new Atlantic subduction zone 50 million years into the future, which will then move down into the Earth's mantle. The new geodynamic model explains the evolution of the Gibraltar subduction zone and its likely development, which will contribute to the renewal of the



The three Atlantic subduction zones, in gray.
Credit: ill./©: João Duarte

Atlantic Ocean floor. The findings are the result of many years of collaboration between the partners in Lisbon and Mainz and have been published recently in *Geology*.

Oceans have individual lifetimes

Oceans come into existence and grow, but eventually they shrink and close – a sequence of events known as the Wilson cycle. One of the cornerstones of this cycle is the initiation of subduction, i.e., when the oceanic lithosphere returns to the Earth's mantle to be recycled. "The Atlantic Ocean is unique because here there are hardly any subduction zones, in contrast with the Pacific," said Professor Boris Kaus of JGU. The only fully developed subduction zones in the Atlantic with volcanic island arcs are the Lesser Antilles arc in the Caribbean and the Scotia arc between the southern tip of Argentina and the Antarctic, both formed in the Cretaceous period. "The Gibraltar arc that is now about to invade the Atlantic is the third," explained Kaus, head of the Geodynamics and Geophysics group at JGU. The Atlantic is thus a unique laboratory that enables the analysis of subduction initiation.

The Gibraltar arc came into being as part of subduction zones that have developed in the Western Mediterranean since the Oligocene epoch some 30 million years ago. Most of the arc is today present under the Alborán Sea, the westernmost portion of the Mediterranean Sea, extending already into the Atlantic. Its propagation to the west has slowed down over the past 5 million years, leading some researchers to conclude that it may possibly have become completely inactive. "We do not share this view," emphasized Professor Boris Kaus and Dr. Nicolas Riel. "Our computer simulations allow us to accurately reconstruct the physical development of the Gibraltar arc and assess its future development." For their calculations, the research team used the MOGON II supercomputer at JGU.

Migration into the Atlantic will recommence after a period of quiescence

The simulations start at a period 30 million years ago and show the arc of the subduction zone gradually moving from the French/Spanish Mediterranean region towards the south. Some 17 million years ago, the center of the arc reached North Africa. Islands, such as the Kabylies, wandered with this southward movement and became attached to the North African mainland. "Our model also helps explain certain geological observations," said Professor Boris Kaus. Roughly 10 million years ago, the so-called slab, which is the part of the lower plate that already descends into the mantle, began to push toward the Atlantic. The Atlantic subduction zone of the Gibraltar arc is currently on a line that approximately corresponds with that of the border between Spain and Portugal.

The geophysicists in Mainz and Lisbon expect the rate of expansion of the arc to decelerate in the future so that it will come almost to a standstill in about 20 million years. Following that, the rate of migration will pick up so that – over the following 30 million years – the subduction zone will spread into the Atlantic in the form of a semicircle, creating a new Atlantic subduction system.

The model reproduces the propagation of a subduction zone from a closing ocean – in this case, the Mediterranean – through a narrow oceanic corridor into a new opening ocean, the Atlantic. "Our simulations have shown for the first time that this form of direct migration can occur," added Professor João Duarte of Universidade de Lisboa, lead author of the published article.

Video:

https://ulisboa-my.sharepoint.com/:v:/g/personal/jdduarte_fc_ul_pt/EYwb-OSqo1BAqL9Ir4xw7CgB-Up99DeUAnOxEe06MMwbyg?e=9y3Tj5

Simulation showing the development of the Gibraltar subduction zone over time

video/©: Nicolas Riel und João Duarte

Journal Reference: João C. Duarte; Nicolas Riel; Filipe M. Rosas; Anton Popov; Christian Schuler; Boris J.P. Kaus, **Gibraltar subduction zone is invading the Atlantic.** *Geology* (Feb. 13, 2024) https://doi.org/10.1130/G51654.1.

Loathed by scientists, loved by nature: sulfur and the origin of life

A University of Arizona-led study shines a spotlight on sulfur, a chemical element that, while all familiar, has proved surprisingly resistant to scientific efforts in probing its role in the origin of life

EurekAlert! March 13, 2024
Source: University of Arizona

Many artists have tried to depict what Earth might have looked like billions of years ago, before life made its appearance. Many scenes trade snow-covered mountains for lava-gushing volcanoes and blue skies for lightning bolts pummeling what's below from a hazy sky.

But what did early Earth actually look like? This question has been the subject of intense scientific research for decades.

A publication led by Sukrit Ranjan, an assistant professor in the University of Arizona's Lunar and Planetary Laboratory, shines a spotlight on sulfur, a chemical element that, while all familiar, has proved surprisingly resistant to scientific efforts in probing its role in the origin of life.

"Our picture of early Earth is pretty fuzzy," said Ranjan, who explores sulfur concentrations in early Earth's waters and atmosphere. The same processes that make our planet habitable – liquid water and plate tectonics – constantly destroy the rocks that hold Earth's geologic record, he argues. "It's great for us because it recycles nutrients that would otherwise be locked up in Earth's crust, but it's terrible for geologists in the sense that it removes the messengers."

Published in the journal *AGU Advances* in December, Ranjan's paper was selected as an editor's highlight, in recognition of "experiments that were extremely difficult to perform but provide constraints for ongoing laboratory prebiotic chemistry experiments."

At the core of efforts to pull back the curtain on the emergence of life on Earth has been a concept known as the "RNA world," Ranjan said, referring to ribonucleic acid, a class of molecules that are present in every living cell and crucial to life as we know it.

The RNA world hypothesis is based on an interesting feature of modern biology, which is that of the four major categories of biomolecules – amino acids, carbohydrates, lipids and nucleic acids – RNA is the only one that can perform the role of an enzyme and the storage and replication of genetic information, by making copies of itself, all by itself. There's just one problem: It's really hard to make.

"For about 50 years, people have tried to figure out how to make RNA without enzymes, which is how biology does it," Ranjan said, explaining that it wasn't until the last five years that researchers figured out non-enzymatic pathways to make RNA.

"If we can get RNA, then on the far horizon we see a pathway to get everything else going," he said. "And this begs the question: Was this molecule actually available earlier in any quantities whatsoever? And this is actually a major open question."

Recently, scientists have completed a half-century quest to make RNA molecules without biological enzymes, a huge step forward to demonstrating the RNA world. However, these chemical pathways all rely on a critical sulfur molecule, called sulfite. By studying rock samples from some of Earth's oldest rocks, scientists know there was plenty of sulfur to go around on the early, prebiotic Earth. But how much of it was in the atmosphere? How much of it ended up in water? And how much of it ended up as RNA-producing sulfite? Those are the questions Ranjan and his team set out to answer.

"Once it's in the water, what happens to it? Does it stick around for a long time, or does it go away quickly?" he said. "For modern Earth we know the answer – sulfite loves to oxidize, or react with oxygen, so it'll go away super-fast."

By contrast, as geological evidence indicates, there was very little oxygen in early Earth's atmosphere, which could have allowed sulfite to accumulate and last much longer. However, even in the absence of oxygen, sulfite is very reactive, and many reactions could have scrubbed it from the early Earth environment.

One such reaction is known as disproportionation, a process by which several sulfites react with each other, turning them into sulfate, and elemental sulfur, which are not useful for origin-of-life chemistry. But how fast is this process? Would it have allowed for sufficient quantities of sulfites to build up to kickstart life?

"No one has actually looked into this in depth outside of other contexts, mainly wastewater management," Ranjan said. His team then set out to investigate this problem under various conditions, an effort that took five years from designing the experiments to publishing the results.

"Of all the atoms that stock the prebiotic shipyard, including carbon, hydrogen, nitrogen, oxygen, phosphorus and sulfur, sulfur is perhaps the thorniest," wrote Sonny Harman of NASA's Ames Research Center, in a viewpoint article accompanying the publication. Because of its eagerness to enter into chemical reactions,

"sulfur compounds tend to be more unstable, posing hazards to lab personnel and equipment, clogging up instrumentation and gumming up experiments."

A lab tech's nightmare

In their setup, Ranjan and his co-authors dissolved sulfite in water at various levels of acidity or alkalinity, locked it into a container under an oxygen-free atmosphere and let it "age," as Ranjan put it. Every week, the team measured the concentrations of various sulfites with ultraviolet light. At the end of the experiment, they subjected them to a suite of analyses, all geared toward answering a relatively simple question, he said: "Just how much of this original molecule is left, and what did it turn into?"

Sulfites, it turned out, disproportionate much slower than what conventional wisdom held. Earlier studies, for example, had floated the idea of a sulfur haze engulfing the early Earth, but Ranjan's team found that sulfites break down under ultraviolet light more quickly than expected. In the absence of an ozone layer during Earth's early days, this process, known as photolysis, would have quickly purged sulfur compounds from the atmosphere and the water, albeit not quite as efficiently as the abundant oxygen in today's world.

While it's plausible that slow disproportionation could have allowed sulfites to accumulate, photolysis would have made that very unlikely except in certain environments such as shallow water pools, shaded from UV radiation, particularly if fed by surface runoff to provide mineral shields. Examples include underground pools or closed basin carbonate lakes, drainage-less depressions where sediments accumulate but water can only leave by evaporation.

"Think bodies of water like the Great Salt Lake in Utah or Mono Lake in California," Ranjan said, adding that hydrothermal environments are emerging as hot candidates for life's first appearance. Here, groundwater carrying dissolved minerals comes into contact with heat from volcanic activity, creating unique micro-environments that offer "safe spaces" for chemical processes that could not occur elsewhere.

Such places can be found at mid-ocean ridges in the deep sea, but also on land, Ranjan said. "A modern-day example of this is Yellowstone National Park, where we find pools that accumulate lots of sulfite, despite the oxygen," he said, "and that can happen just because the sulfite is continually being replenished by volcanic outgassing."

The study provides opportunities to test the hypothesis of sulfite availability in the evolution of the first molecules of life experimentally, the authors point out. Ranjan said one field of research in particular has him excited – phylogenetic microbiology, which uses genome analysis to reconstruct the blueprints of sulfur-using microorganisms believed to represent the oldest phyla on Earth.

There is evidence that these bacteria gain energy by reducing highly oxidized forms of sulfur to less oxidized ones. Intriguingly, Ranjan pointed out, they depend on a fairly complex enzyme machinery for the first step, reducing sulfate, sulfur's abundant "modern" form, to sulfite, suggesting these enzymes are the product of a long evolutionary process. In contrast, only one enzyme is involved in the conversion from sulfite – the proposed key ingredient in "prebiotic puddle environments" – to sulfide.

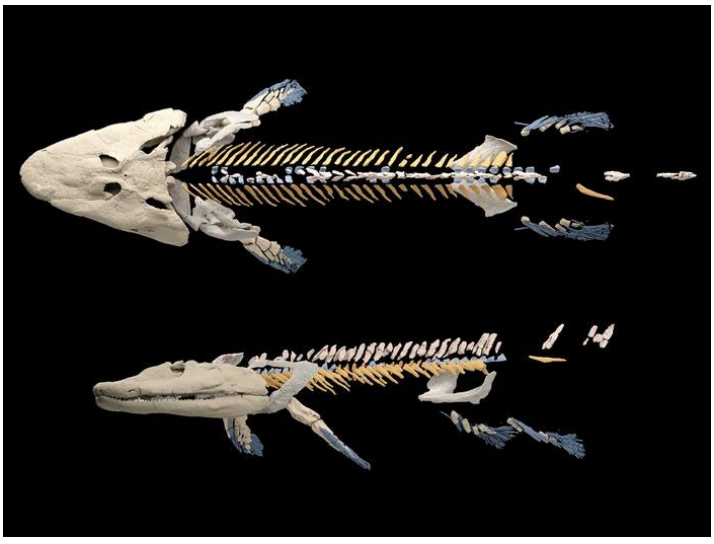
"If true, this implies that sulfite was present in the natural environment in at least some water bodies, similar to what we argue here," he said. "Geologists are just now turning to this. Can we use ancient rocks to test if they're rich in sulfite? We don't know the answer yet. This is still cutting-edge science."

Journal Reference: **Geochemical and Photochemical Constraints on S[IV] Concentrations in Natural Waters on Prebiotic Earth**, *AGU Advances,* 15-Dec-2023. DOI: 10.1029/2023AV000926.

In the evolution of walking, the hip bone connected to the rib bones

New data from a 375-million-year-old fossil fish gives clues to changes in the axial skeleton that might have helped our ancestors climb out of the water

EurekAlert! (from AAAS), 5-Apr-2024
Source: Penn State University



New reconstruction of the skeleton of the 375-million-year-old fossil fish, *Tiktaalik roseae*. In a new study, researchers used Micro-CT to reveal vertebrae and ribs of the fish that were previously hidden beneath rock. The new reconstruction shows that the fish's ribs likely attached to its pelvis, an innovation thought to be crucial to supporting the body and for the eventual evolution of walking.

Credit: Thomas Stewart, Penn State

UNIVERSITY PARK, Pa. — Before the evolution of legs from fins, the axial skeleton — including the bones of the head, neck, back and ribs — was already going through changes that would eventually help our ancestors support their bodies to walk on land. A research team including a Penn State biologist completed a new reconstruction of the skeleton of *Tiktaalik*, the 375-million-year-old fossil fish that is one of the closest relatives to limbed vertebrates. The new reconstruction shows that the fish's ribs likely attached to its pelvis, an innovation thought to be crucial to supporting the body and for the eventual evolution of walking.

A paper describing the new reconstruction, which used microcomputed tomography (micro-CT) to scan the fossil and reveal vertebrae and ribs of the fish that were previously hidden beneath rock, appeared April 2 in the journal *Proceedings of the National Academy of Sciences*.

"Tiktaalik was discovered in 2004, but key parts of its skeleton were unknown," said Tom Stewart, assistant professor of biology in the Eberly College of Science at Penn State and one of the leaders of the research team. "These new high-resolution micro-CT scans show us the vertebrae and ribs of *Tiktaalik* and allow us to make a full reconstruction of its skeleton, which is vital to understanding how it moved through the world."

Unlike most fish, which have vertebrae and ribs that are the same along the length of the trunk, the axial skeletons of limbed vertebrates show dramatic differences in the vertebrae and ribs from the head region to the tail region. The evolution of this regionalization allowed the performance of specialized functions, one of which was a mechanical linkage between ribs in the sacral region to the pelvis that enabled support of the body by the hind limbs.

The pelvic fins of fish are evolutionarily related to hind limbs in tetrapods — four-limbed vertebrates, including humans. In fish, the pelvic fins and bones of the pelvic girdle are relatively small and float freely in the body. For the evolution of walking, the researchers explained, the hind limbs and pelvis became much larger and formed a connection to the vertebral column as a way of bracing the forces related to supporting the body.

"*Tiktaalik* is remarkable because it gives us glimpses into this major evolutionary transition," Stewart said. "Across its whole skeleton, we see a combination of traits that are typical of fish and life in water as well as traits that are seen in land-dwelling animals."

The original description of *Tiktaalik* focused on the front portion of the skeleton. Fossils were meticulously prepared to remove the surrounding matrix of rock and expose the skull, shoulder girdle and pectoral fins. The ribs in this area were large and expanded, suggesting that they may have supported the body in some way, but it was unclear exactly how they would have functioned. In 2014, the fish's pelvis, discovered in the same location as the rest of the skeleton, was also cleaned of matrix and described.

"From past studies, we knew that the pelvis was large, and we had a sense that the hind fins were large too, but until now couldn't say if or how the pelvis interacted with the axial skeleton," Stewart said. "This reconstruction shows, for the first-time, how it all fit together and gives us clues about how walking might have first evolved."

The researchers explained that, unlike our own hips where our bones fit tightly together, the connection between the pelvis and axial skeleton of Tiktaalik was likely a soft-tissue connection made of ligaments.

"*Tiktaalik* had specialized ribs that would have connected to the pelvis by a ligament," Stewart said. "It's astonishing really. This creature has so many traits — large pair of hind appendages, large pelvis, and connection between the pelvis and axial skeleton — that were key to the origin of walking. And while *Tiktaalik* probably wasn't walking across land, it was definitely doing something new. This was a fish that could likely prop itself up and push with its hind fin."

The new reconstruction of the skeleton also sheds light on specializations for head mobility in *Tiktaalik* and new details of the fish's pelvic fin anatomy.

"It's incredible to see the skeleton of *Tiktaalik* captured in such vivid detail," said Neil Shubin, Robert R. Bensley Distinguished Service Professor of Organismal Biology and Anatomy at the University of Chicago and one of the authors of the paper. "This study sets the stage for ones that explore how the animal moved about and interacted with its environment 375 million years ago."

In addition to Stewart and Shubin, the research team includes Justin B. Lemberg, Emily J. Hillan, and Isaac Magallanes at The University of Chicago, and Edward B. Daeschler at Academy of Natural Sciences of Drexel University.

Support from the Brinson Foundation, the Biological Sciences Division of The University of Chicago, an anonymous donor to the Academy of Natural Sciences of Drexel University, and the U.S. National Science Foundation funded this research. Fieldwork was made possible by the Polar Continental Shelf Project of Natural Resources, Canada; the Department of Heritage and Culture, Nunavut; the hamlets of Resolute Bay and Grise Fiord of Nunavut; and the Iviq Hunters and Trappers of Grise Fiord.

Journal: *Proceedings of the National Academy of Sciences*. **The axial skeleton of Tiktaalik roseae.** DOI: 10.1073/pnas.231610612.

Evolution of the most powerful ocean current on Earth

Ocean sediment cores reveal climate-related fluctuations in the Antarctic Circumpolar Current in past epochs

EurekAlert! March 27, 2024
Source: Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research

The Antarctic Circumpolar Current plays an important part in global overturning circulation, the exchange of heat and CO_2 between the ocean and atmosphere, and the stability of Antarctica's ice sheets. An international research team led by the Alfred Wegener Institute and the Lamont-Doherty Earth Observatory have now used sediments taken from the South Pacific to reconstruct the flow speed in the last 5.3 million years. Their data show that during glacial periods, the current slowed; during interglacials, it accelerated. Consequently, if the current global warming intensifies in the future, it could mean that the Southern Ocean stores less CO_2 and that more heat reaches Antarctica. The study was just released in the journal *Nature*.

What moves 100 times as much water as all the Earth's rivers combined, measures 2,000 kilometers across at its widest point, and extends all the way down to the deep sea? The Antarctic Circumpolar Current (ACC). In the past, this ocean current system, the most powerful on Earth, was subject to substantial natural fluctuation, as recent analyses of sediment cores have revealed. Colder phases in the Pliocene and subsequent Pleistocene, during which the ACC slowed, correlate to advances of the West Antarctic Ice Sheet. In warmer phases the ACC accelerated, accompanied by the retreat of the ice sheet. "This loss of ice can be attributed to increased heat transport to the south," says Dr Frank Lamy, a researcher in the Marine Geology Division of the Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research (AWI) and first author of the Nature study. "A stronger ACC means more warm deep water reaches the ice-shelf edge of Antarctica."

"The ACC has a major influence on heat distribution and CO_2 storage in the ocean. Until recently, it remained unclear how the ACC responds to climate fluctuations, and whether changes in the ACC offset or amplify the effects of warming," says Lamy. "Therefore, to improve forecasts of our future climate and the stability of the Antarctic Ice Sheet using computer simulations, we need paleo-data that can tell us something about the intensity of the ACC in past warm phases in Earth's history."

To gather that data, in 2019 an international expedition led by Lamy and geochemist Prof Gisela Winckler from the Lamont-Doherty Earth Observatory, Columbia University (USA) ventured to the central South Pacific on board the drilling ship JOIDES Resolution. There, in the subantarctic zone, the research team extracted two extensive drill cores, gathered at a depth of 3600 meters. "The drill sites are in the vicinity of Point Nemo, the point on the Earth that is farthest from any landmass or island, where the ACC flows without any influences from continental landmasses," explains Prof Helge Arz, a marine geologist at the Leibniz Institute for Baltic Sea Research in Warnemünde and one of the study's main authors. "Using the sediment deposits in this region, we can reconstruct its mean flow speed in the past."

The 145- and 213-metre-deep drill cores in the South Pacific were part of the International Ocean Discovery Program (IODP), the goal of which is to unlock Earth's history on the basis of geochemical traces left behind in marine sediments and rock formations under the seafloor. They were preceded by extensive reconnaissance work done on various expeditions with the research vessel Polarstern. The sediment cores date back 5.3 million years and encompass three entire epochs:

- the Pliocene, during which it was up to three degrees warmer than today and the atmospheric CO_2 concentration, at more than 400 ppm, was similar to today's;
- the Pleistocene, which began 2.6 million years ago and was characterized by alternating ice ages (glacials) and warm periods (interglacials);
- and the Holocene, a warm period that began roughly 12,000 years ago, following the last ice age, and continues up to the present.

Drawing on the layers in the cores, which correspond to different epochs, the experts analyzed the size distribution of the sediment particles, which are deposited differently on the seafloor, depending on the water's flow speed. This allowed them to trace the evolution of the ACC since the early Pliocene, when a prolonged cooling of the climate began. Sediment cores from previous Polarstern cruises to the South Pacific offered additional clues on the dynamics of the ACC.

Their findings show that, up to three million years ago in the Pliocene, the ACC first accelerated as the Earth gradually cooled. This was due to a growing temperature gradient between the Equator and Antarctica, which produced powerful westerly winds – the main motor of the ACC. Despite the prolonged cooling, it then began to slow. "The switch came at a time when the climate and the circulation in the atmosphere and the ocean experienced major changes," says Frank Lamy. "2.7 million years ago, at the end of the Pliocene, broad expanses of the Northern Hemisphere were covered in ice and the Antarctic ice sheets expanded. This was due to changes in ocean currents, set off by tectonic processes, together with a

long-term cooling of the ocean and decreasing atmospheric CO_2 levels."

With regard to the last 800,000 years, in which the atmospheric CO_2 levels varied from 170 to 300 ppm, the researchers were able to identify a close connection between ACC strength and glacial cycles: during warm periods, in which the atmospheric CO_2 levels rose, the flow speed increased by up to 80 percent compared to the present; during ice ages, it decreased by up to 50 percent. At the same time, during transitions between interglacials and glacials there was a shift in the ACC's position and therefore in the upwelling of nutrient-rich deep water in the Southern Ocean, as geochemical sediment analyses revealed. They show that the silicate shells of diatoms – the most important phytoplankton in the Southern Ocean – were deposited on the seafloor farther north in ice ages than in warm periods.

"A weaker ACC and lower atmospheric CO_2 levels during the ice ages of the Pleistocene indicate less pronounced upwelling and more stratification in the Southern Ocean, that is, more CO_2 storage," says Gisela Winckler. Due to anthropogenic climate change, the study concludes, the ACC could grow stronger in the future. This could impact the CO_2 balance of the Southern Ocean and lead to accelerated melting of Antarctic ice.

Background: The Antarctic Circumpolar Current

As a circular current flowing clockwise around Antarctica, the Antarctic Circumpolar Current (ACC) connects the Atlantic, Pacific and Indian Oceans. As such, it has a pivotal role in global ocean circulation and, through the Atlantic conveyor belt, ultimately influences the climate in Europe. Driven by the powerful westerly winds of the subantarctic zone, and by temperature and salinity differences between the subtropics and the Southern Ocean, the ACC forms a barrier for the warm surface water of the subtropics on its way to the Antarctic. At the same time, comparatively warm deep water from the Atlantic and Pacific flows into it. Large ocean gyres that are formed in the ACC and wander south, together with the upwelling of deep water, transport heat to the ice shelves on the continental margin, especially in the Pacific sector of the Antarctic. Moreover, the upwelling produced by the ACC brings nutrients to the surface, which drives algal growth while amplifying biological carbon export to the deep sea in the process – but also the transport of CO_2, which is released into the atmosphere.

Journal Reference: *Nature.* **Five million years of Antarctic Circumpolar Current strength variability.** 27-Mar-2024. DOI: 10.1038/s41586-024-07143-3.

New geological study: Scandinavia was born in Greenland

The oldest Scandinavian bedrock was 'born' in Greenland according to a new geological study from the University of Copenhagen. The study helps us understand the origin of continents and why Earth is the only planet in our solar system with life.

EurekAlert! March 21, 2024
Source: University of Copenhagen - Faculty of Science

In a Finnish outcrop nestled between some of Northern Europe's oldest mountains, researchers have found traces of a previously hidden part of Earth's crust that points more than three billion years back in time and north towards Greenland.

These traces were found in the mineral zircon, which after chemical analyses, indicated to researchers from the Department of Geosciences and Natural Resource Management that the "foundation" upon which Denmark and Scandinavia rest, was probably 'born' from Greenland approximately 3.75 billion years ago.

"Our data suggest that the oldest part of Earth's crust beneath Scandinavia originates in Greenland and is about 250 million years older than we previously thought," says Professor Tod Waight, a geologist at the Department of Geosciences and Natural Resource Management.

The researchers' study of the zircon showed that, in several ways, its chemical fingerprint matches those of some of the oldest rocks on the planet found in West Greenland's North Atlantic Craton.

"The zircon crystals we found in river sand and rocks from Finland have signatures that point towards them being much older than anything ever found in Scandinavia, while matching the age of Greenlandic rock samples. At the same time, the results of three independent isotope analyses confirm that Scandinavia's bedrock was most likely linked to Greenland," says Department of Geosciences and Natural Resource Management researcher Andreas Petersson.

A water world without oxygen

Denmark, Sweden, Norway and Finland rest atop a part of Earth's crust known as the Fennoscandian Shield, or the Baltic Shield. The researchers believe that it broke away from Greenland as a "seed" and shifted for hundreds of millions of years until it "took root" where Finland is today.

Here, the plate grew as new geological material accumulated around it, until it became Scandinavia. At the time of the crust's detachment from Greenland, the planet looked very different than today.

"Earth was probably a watery planet, like in the movie Waterworld, but without any oxygen in the atmosphere and without emergent crust. But, because that's so far back in time, we can't be really be sure about what it actually looked like," says Tod Waight.

According to the researchers, the fact that Earth even has a continental crust composed of granite is quite special when they look out into space and compare it with other planets in our galactic neighborhood.

"This is unique in our solar system. And, evidence of liquid water and a granite crust are key factors when trying to identify habitable exoplanets and the possibility of life beyond Earth," explains Andreas Petersson.

Continents are the key to life

The new study adds pieces to a primordial continental puzzle that began long before life on Earth truly blossomed, but which has largely paved the way for both human and animal life.

"Understanding how continents formed helps us understand why ours is the only planet in the solar system with life on it. Because without fixed continents and water in between them, we wouldn't be here. Indeed, continents influence both ocean currents and climate, which are crucial for life on Earth," says Andreas Petersson.

Furthermore, the new study contributes to a growing number of studies which reject the means used thus far to calculate how continents have grown – especially during the first billion years of Earth's history.

"The most commonly used models assume that Earth's continental crust began to form when the planet was formed, about 4.6 billion years ago. Instead, our and several other recent studies suggest that the chemical signatures showing growth of the continental crust can only be identified about a billion years later. This means that we may need to revise much of what we thought about how early continents evolved," says Professor Waight.

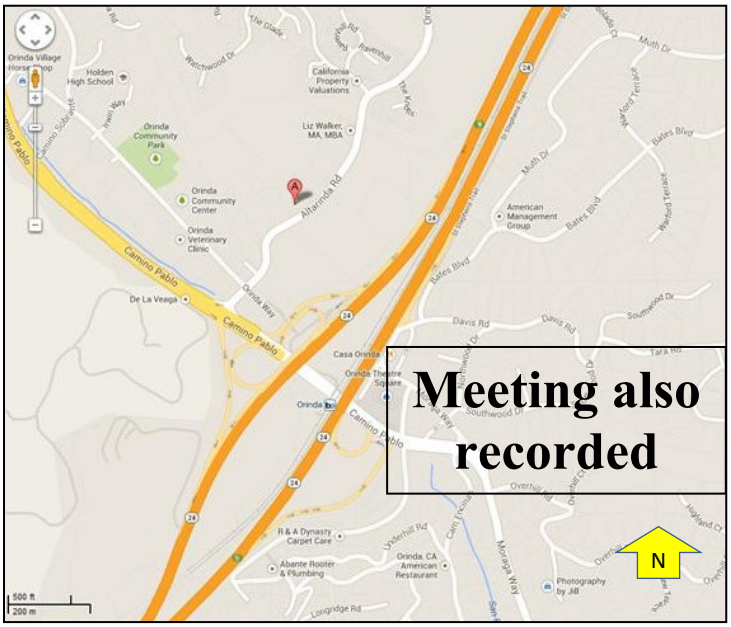
At the same time, results of the study add to previous research that found similar "seeds" from ancient crusts in other parts of the world.

"Our study provides us with another important clue in the mystery of how continents formed and spread across Earth – especially in the case of the Fennoscandian Shield. But there is still plenty that we don't know. In Australia, South Africa and India, for example, similar seeds have been found, but we're unsure of whether they all come from the same "birthplace," or whether they originated independently of one another in several places on Earth. This is something that we would like to investigate more using the method we used in this study," concludes Professor Waight.

About the study

- The study demonstrates that the oldest part of Earth's crust beneath Scandinavia comes from Greenland and is about 250 million years older than once thought.
- Therefore, Denmark and Scandinavia's geologic foundation was most likely connected to Greenland approximately 3.75 billion years ago.
- The researchers analysed zircons from modern river sand and rock samples from the remote Pudasjärvi and Suomujärvi regions of Finland, whose geological origins have been little studied.
- The zircon crystals found in the Finnish river sand originally crystallized in granitic magmas deep within the crust. These granites were then lifted to the surface and eroded to eventually form sand.
- The researchers used isotopic compositions of lead, hafnium and oxygen to trace the chemical fingerprint from the Fennoscandian Shield back to Greenland.

Journal Reference: **An Eoarchean continental nucleus for the Fennoscandian Shield and a link to the North Atlantic craton.** *Geology,* 28-Dec-2023. DOI: 10.1130/G51658.1.



Biography:

Nick Swanson-Hysell is a geologist who is an Associate Professor of Earth and Planetary Science at UC Berkeley. His research program focuses on the long-term evolution of Earth with a particular emphasis on paleogeography and its connections with climate. His teaching includes field courses including instruction of the storied Berkeley Hills field geology course (currently called EPS 101: Field Geology and Digital Mapping).

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